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Mimura et al.

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(54) **OPTICAL ELEMENT, AND LIGHTING
DEVICE, DISPLAY DEVICE AND
ELECTRONIC DEVICE THAT USE THE
OPTICAL ELEMENT**

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(52) **U.S. Cl.** **349/66**

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359/613; 349/55-166; 428/1.1-1.62
See application file for complete search history.

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Primary Examiner — Stephone Allen

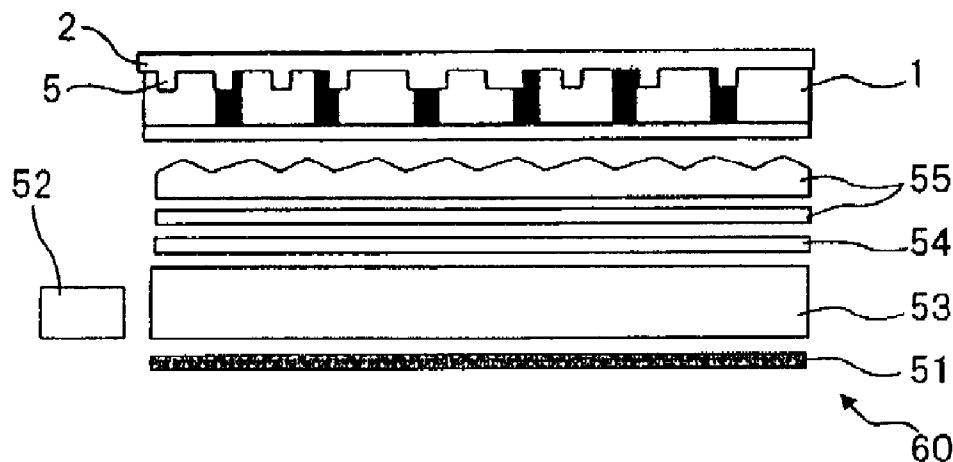
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(57) **ABSTRACT**

A micro-louver (1) includes: a transparent substrate (2); a
concavoconvex shape portion (5) formed on at least one sur-
face of the transparent substrate (2) and in a prescribed pattern
for diffracting incident light to form an image; and a light
controlling layer (7) including at least one transparent layer
(3) and at least light-absorption layer (4) arranged alternately
on said at least one surface of the transparent substrate (2),
each of said at least one transparent layer (3) and said at least
one transparent layer (4) extending in a direction that inter-
sects said at least one surface of the transparent substrate (2).

9 Claims, 7 Drawing Sheets



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Fig. 1

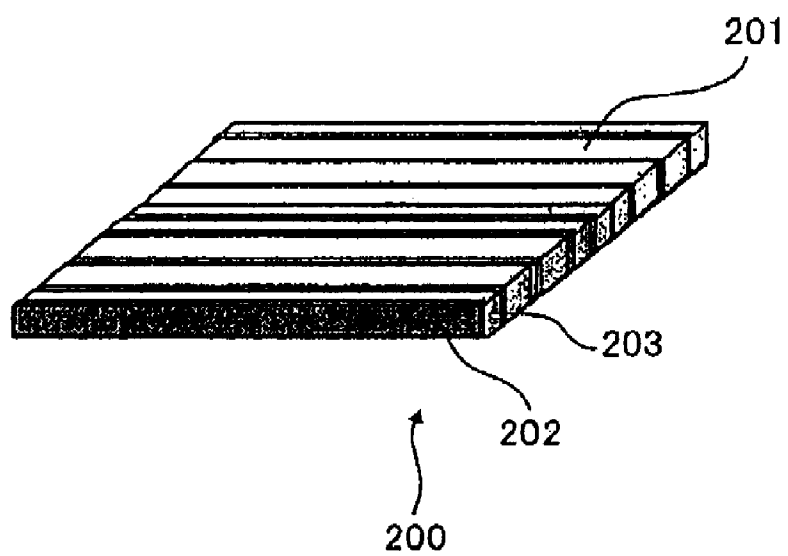


Fig. 2

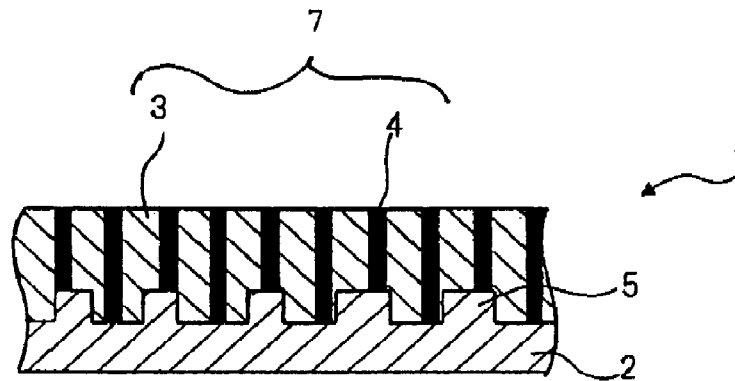


Fig. 3

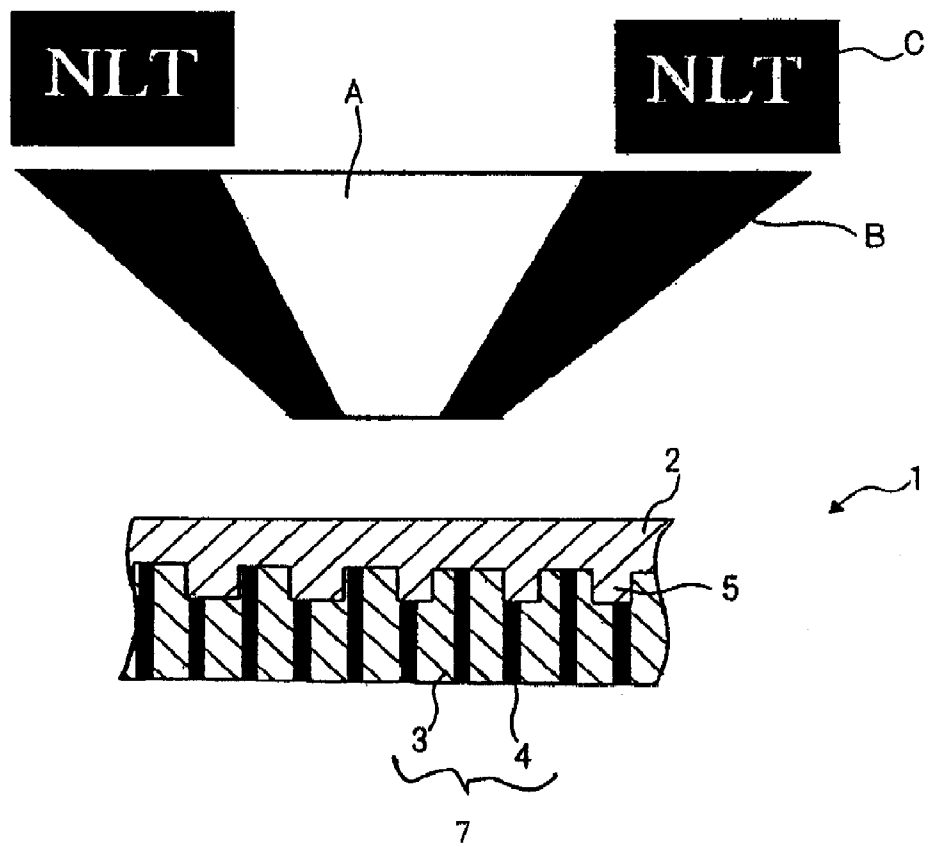


Fig. 4

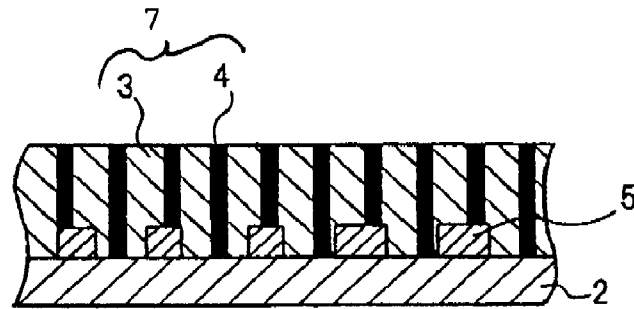


Fig. 5

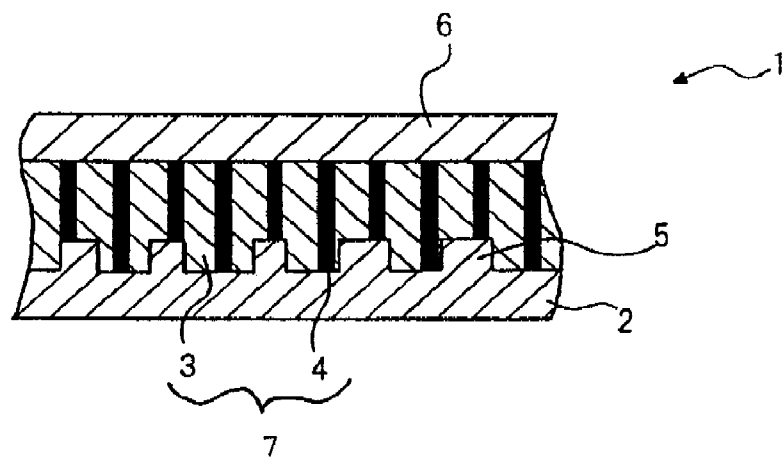


Fig. 6

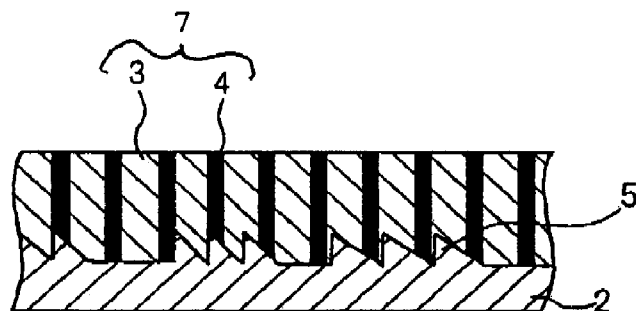


Fig. 7

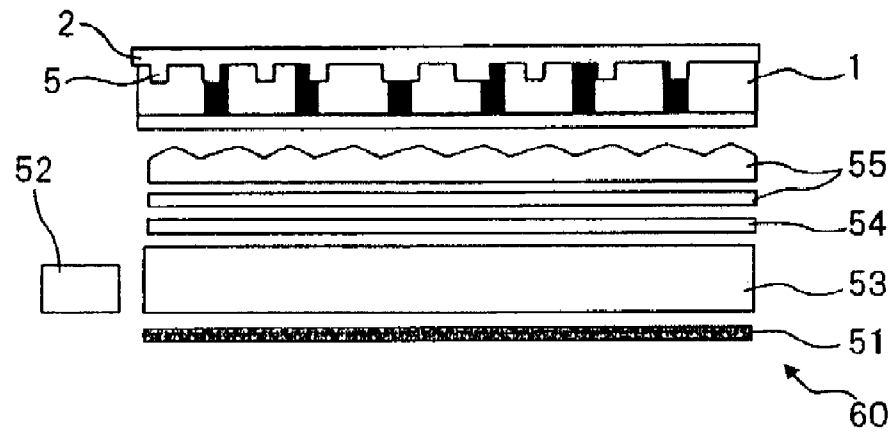


Fig. 8

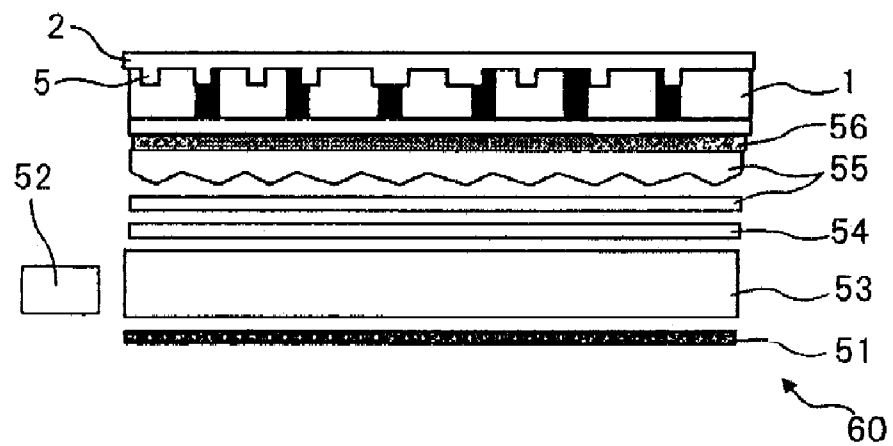


Fig. 9

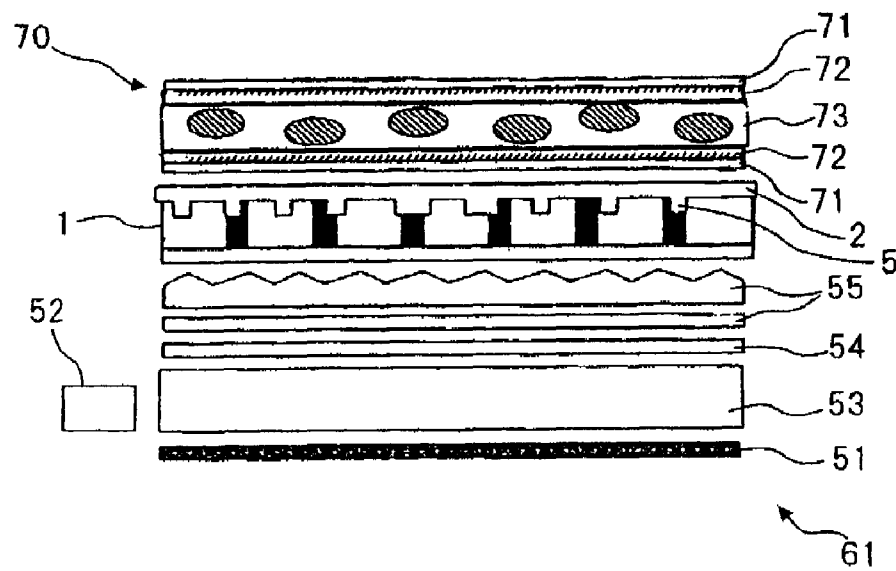


Fig. 10

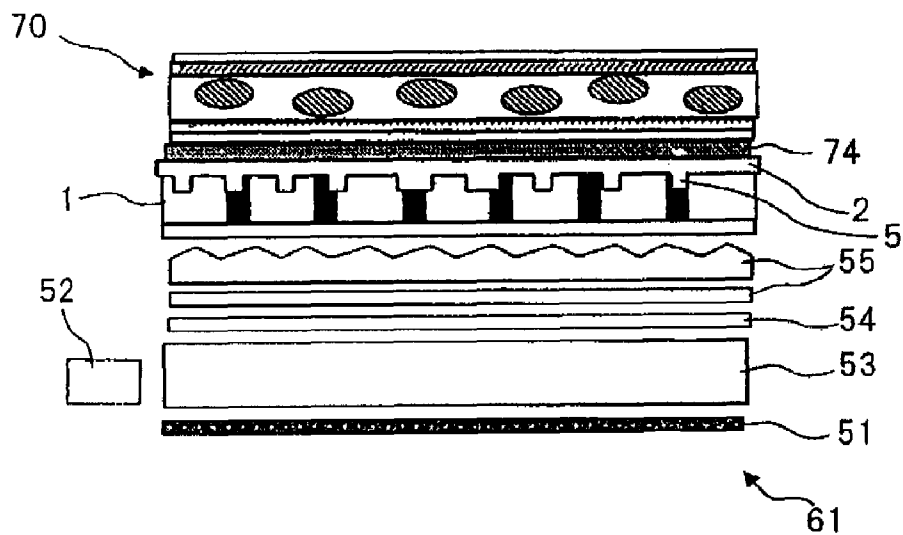


Fig. 11

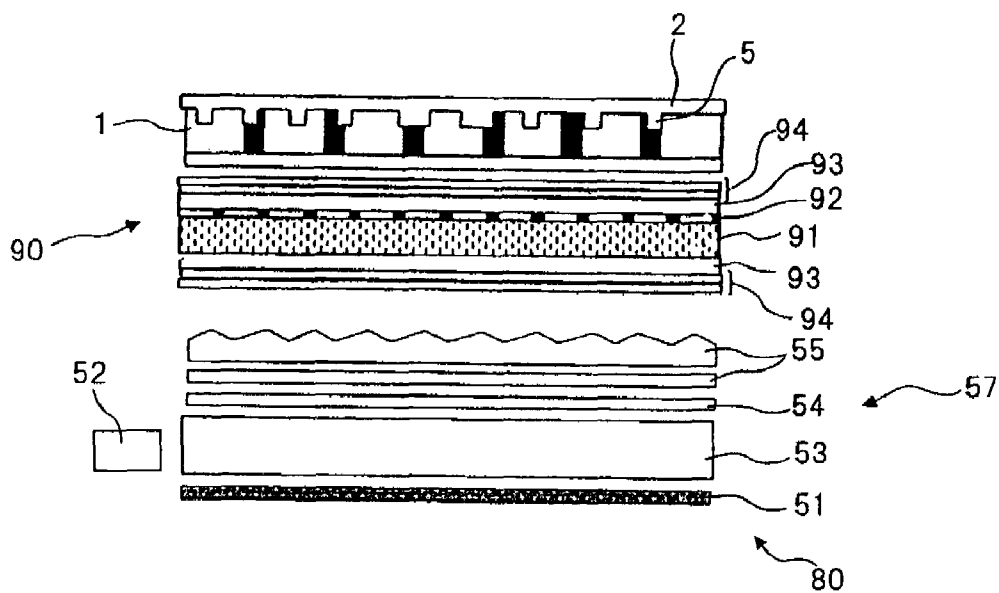


Fig. 12

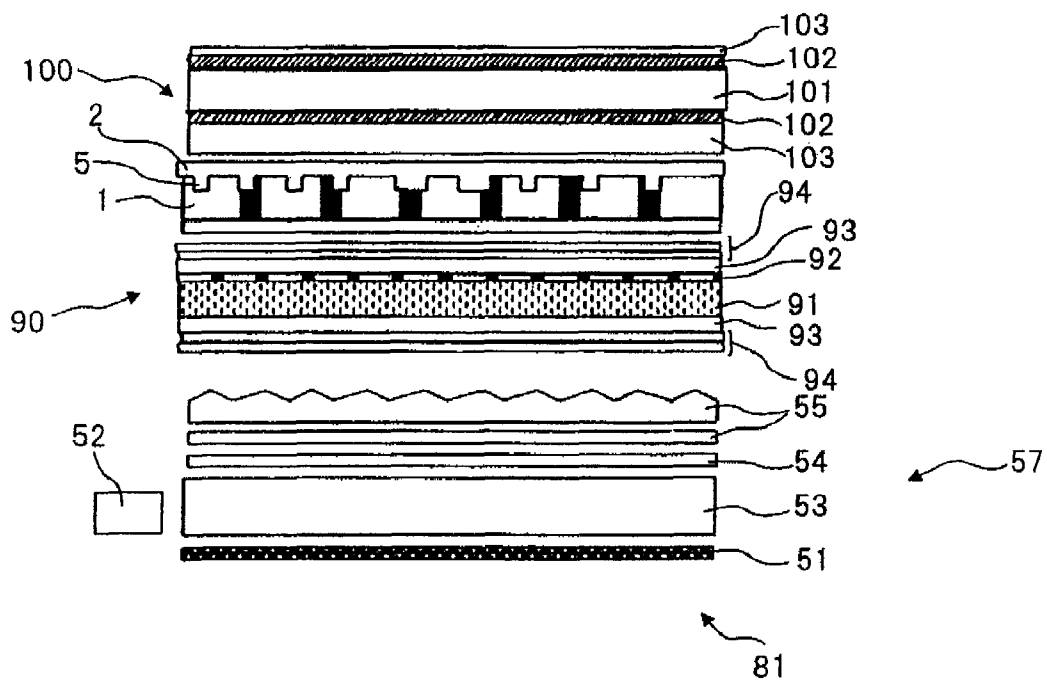


Fig. 13

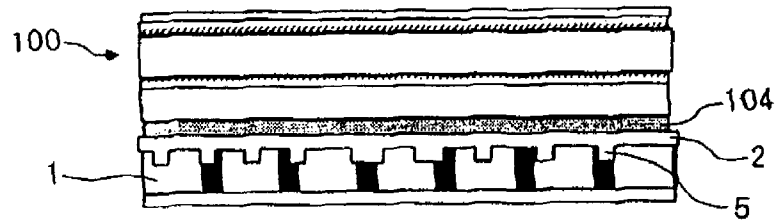


Fig. 14

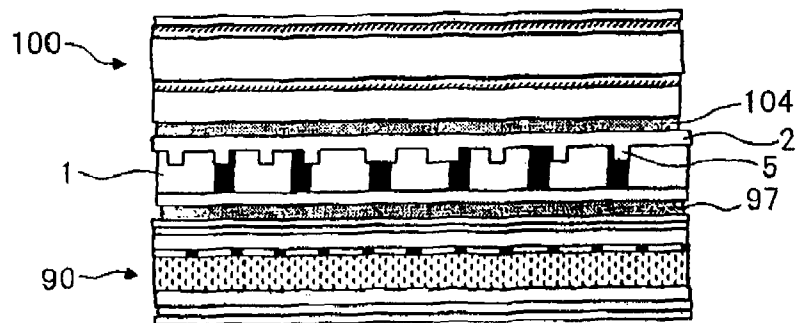


Fig. 15

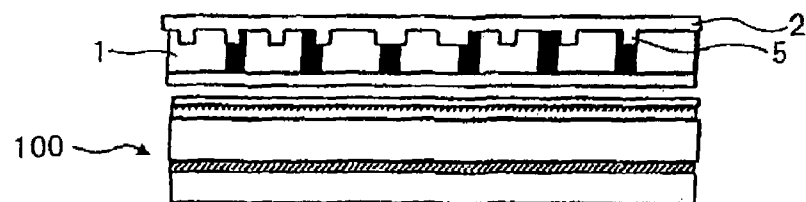
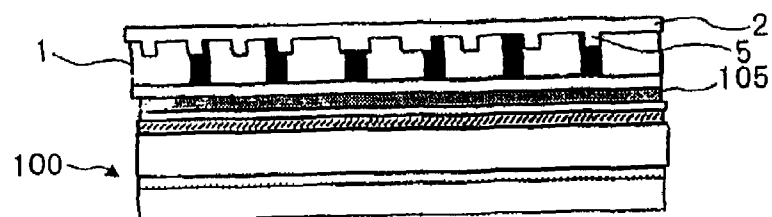


Fig. 16



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OPTICAL ELEMENT, AND LIGHTING DEVICE, DISPLAY DEVICE AND ELECTRONIC DEVICE THAT USE THE OPTICAL ELEMENT

This application is a continuation of application Ser. No. 11/866,543 filed Oct. 3, 2007 which claims priority under 35 U.S.C. §119 from Japanese Patent Application No. 2006-279994 filed on Oct. 13, 2006. The entire disclosures of the prior applications, application Ser. Nos. 11/866,543 and JP 2006-279994, are considered part of the disclosure of the accompanying continuation application and are hereby incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an optical element that limits the progression of light in directions that are oblique with respect to a surface, and to a lighting device, a display device and an electronic device that use this optical element.

2. Description of the Related Art

It is in some cases desirable that persons other than the user of a display device are not able to view the display screen. For this purpose, an optical element in the form of film for limiting the progression of light in directions oblique to the surface is known, and such an optical element is referred to as a "micro-louver."

As shown in the publication JP-A-S50-092751 of FIG. 1, relevant micro-louver **200** has a structure in which each of light-absorption portions **202** and each of transparent portions **203** are alternately laminated, each of the portions **202** and **203** extending perpendicular to surface **201**. This micro-louver **200** is arranged on a display surface of a display device, and the light, which is emitted in an oblique direction to the display surface, is limited, such that a display image cannot be viewed from the oblique direction to the display surface.

SUMMARY OF THE INVENTION

The angle region that is laterally oblique to surface **201** of micro-louver **200** as described hereinabove is the region in which light is not emitted in relevant micro-louver **200**. This angle region in which light is not emitted can conceivably be used for the display of images such as for advertising and that differ from the original image that is wished to be blocked from view.

It is therefore an object of the present invention to, in an optical element that limits the emission of light to an angle region that is laterally oblique to the surface, enable the use of the angle region in which the emission of light is limited for the display of images.

The optical element of the present invention for achieving the above-described object includes: a transparent substrate; a concavoconvex shape portion formed on at least one surface of the transparent substrate and in a prescribed pattern for diffracting incident light to form an image; and a light controlling layer including at least one transparent portion and at least light-absorption portion arranged alternately on said at least one surface of the transparent substrate, each of said at least one transparent portion and said at least one light-absorption portion extending in a direction that intersects said at least one surface of the transparent substrate.

According to the optical element of the present invention, the light-absorption portions limit the emission of oblique light to the surface of the transparent substrate. The optical

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element of the present invention further allows the display of a diffraction image formed by a concavoconvex shape portion in the angle region in which the emission of light is limited.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view showing a micro-louver of an example of the related art;

FIG. 2 is a sectional view in the direction of thickness giving a schematic representation of a micro-louver of an embodiment of the present invention;

FIG. 3 is an explanatory view for explaining the operation realized by the micro-louver of FIG. 2;

FIG. 4 is a sectional view showing a modification of the micro-louver of FIG. 2;

FIG. 5 is a sectional view showing another modification of the micro-louver of FIG. 2;

FIG. 6 is a schematic view showing yet another modification of the micro-louver of FIG. 2;

FIG. 7 is a schematic view showing a first example of lighting device that incorporates the micro-louver of the present invention;

FIG. 8 is a schematic view showing a modification of the lighting device of FIG. 7;

FIG. 9 is a schematic view showing a second example of lighting device that incorporates the micro-louver of the present invention;

FIG. 10 is a schematic view showing a modification of the lighting device of FIG. 9;

FIG. 11 is a schematic view showing a first display device that is one example of the incorporation of the micro-louver of the present invention;

FIG. 12 is a schematic view showing a second display device that incorporates the micro-louver of the present invention;

FIG. 13 is a schematic view showing a modification of FIG. 12;

FIG. 14 is a schematic view showing another modification of FIG. 12;

FIG. 15 is a schematic view showing yet another modification of FIG. 12; and

FIG. 16 is a schematic view showing still another modification of FIG. 12.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

Hereinafter, exemplary embodiments of the present invention will be explained with reference to the accompanying drawings below.

FIG. 2 shows a sectional view in the direction of thickness of micro-louver **1** of an embodiment of the present invention. Additionally, in the interest of simplifying explanation, only a few of transparent portions **3**, light-absorption portions **4**, and the concave portions and convex portions of concavoconvex shape portion **5** are shown in FIG. 2. However, these components are actually minute in size and are arranged in a multiplicity on transparent substrate **2**. This simplification also applies to the other figures.

Micro-louver **1** of the present embodiment includes transparent substrate **2**. Concavoconvex shape portion **5** is formed in a prescribed pattern on one surface of transparent substrate **2**. This concavoconvex shape portion **5** constitutes a transmissive-type diffraction grating that generates a prescribed diffraction image. Light controlling layer **7** is further formed on the surface of transparent substrate **2** on which concavoconvex shape portion **5** is formed. Light controlling layer **7**

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includes transparent portions 3 and light-absorption portions 4 that extend perpendicular to the surface of transparent substrate 2. In the example shown in FIG. 2, transparent portions 3 and light-absorption portions 4 are alternately arranged in the right-left direction of the figure. Although not shown in detail, transparent portions 3 and light-absorption portions 4 may also be formed so as to include a prescribed planar pattern such as a grid.

This micro-louver 1 is intended for irradiating light over the surface that is on the side opposite to the side of transparent substrate 2 on which concavoconvex shape portion 5 is formed. At this time, as shown in FIG. 3, light, which is incident to micro-louver 1 in the angle region A that is close to being perpendicular to the surface of micro-louver 1, is transmitted and emitted. On the other hand, light in the angle region B, in which the angle with respect to the surface of micro-louver 1 is small, is blocked by light-absorption portions 4, whereby the light emitted from micro-louver 1 is limited.

Furthermore, a part of the light that passes through the region of micro-louver 1 in which transparent portions 3 are formed and reaches concavoconvex shape portion 5 is diffracted in concavoconvex shape portion 5, whereby a diffraction image that accords with the prescribed pattern is formed. The light that forms this diffraction image is not blocked by light-absorption portions 4 and is therefore emitted to the angle region B. As a result, a fixed image C that corresponds to the diffraction image is visible to an observer located in the angle region B.

In this way, micro-louver 1 of the present embodiment enables the use of angle region B, in which the emission of light is limited, for the display of fixed image C. In addition, light that forms a diffraction image can also be considered to be output to angle region A. However, light that has passed through micro-louver 1 is dominant in angle region A, so that the diffraction image does not stand out.

In micro-louver 1 of the present embodiment, concavoconvex shape portion 5 can be formed by, for example, using a resin part as transparent substrate 2 and then pressing by a die. Alternatively, concavoconvex shape portion 5 may be formed by a different member on the surface of transparent substrate 2, as shown in FIG. 4. Concavoconvex shape portion 5 that is realized by the different member can be formed by utilizing, for example, photolithographic techniques.

The concavoconvex pitch in concavoconvex shape portion 5 that constitutes a diffraction grating in the present embodiment can be on the order of, for example, 0.5 μm -2 μm , and the concavoconvex difference can be set to the order of 0.1 μm -1 μm . In this case, if the angle of emission of transmitted diffraction light is θ_t , the angle of incidence of incident light is θ_i , the diffraction order is m , the wavelength of incident light is λ , and the concavoconvex pitch is p , these values should satisfy the diffraction formula:

$$\sin \theta_t - \sin \theta_i = m\lambda/p$$

Transparent portions 3 and light-absorption portions 4 can be formed using, for example, photolithographic techniques. Namely, transparent resin that is to serve as transparent portions 3 is, for example, applied to transparent substrate 2, and this transparent resin is then patterned by photolithographic techniques. Then, regions of transparent layer 3 that have been removed by the patterning are then filled with the material that is to serve as light-absorption portions 4, whereby transparent portions 3 and light-absorption portions 4 of a prescribed pattern can be obtained.

At this time, the angle region in which the emission of light is limited by micro-louver 1 can be widened according to the

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thickness of light-absorption portions 4 and the narrowness of the formation spacing of light-absorption portions 4. Here, in order to form light-absorption portions 4 at a practical formation spacing so as to obtain micro-louver 1 having a sufficiently broad angle region in which the emission of light is limited, light-absorption portions 4 are preferably formed with sufficient thicknesses. Therefore, a chemically amplified negative photoresist manufactured by the MicroChem Corporation is preferably used as the material of transparent portions 3. This resist has a relatively small molecular weight before exposure to light, and thus is extremely soluble in a solvent of cyclopentanone, propylene glycol methyl ether acetate (PEGMEA), gamma butyrolactone (GBL), or isobutyl ketone (MIBK), whereby the formation of a thick film is facilitated and a film can be formed to a thickness of 100-200 μm . The formation spacing of light-absorption portions 4 is on the order of several tens of micrometers.

A UV-hardening, heat-hardening, or UV/heat-hardening resin to which a coloring material such as a pigment has been added can be used as the material of light-absorption portions 4. Here, a black pigment is basically used as the pigment, but depending on the use, a colored pigment or lame may also be used.

As shown in FIG. 5, micro-louver 1 may be configured in which another transparent substrate 6 is bonded to the side of light controlling layer 7 opposite to the side on which concavoconvex shape portion 5 is formed. In this case, a structure is formed in which transparent portions 3 having a prescribed pattern are sandwiched by transparent substrate 2 and transparent substrate 6. Light-absorption portions 4 of this structure can be formed using a method in which the capillary phenomenon is utilized to fill micro-holes formed between transparent substrate 2 and transparent substrate 6 with the material of light-absorption portions 4.

Here, FIGS. 2 to 5 show a laminar diffraction grating as concavoconvex shape portion 5. However, the diffraction grating of the present invention is not limited to this laminar type, and a blazed diffraction grating may also be configured as shown in FIG. 6.

Further, although a structure has been shown in the present embodiment in which concavoconvex shape portion 5 is formed on the surface of transparent substrate 2 on the side on which transparent portions 3 and light-absorption portions 4 have been provided, a configuration is also possible in which concavoconvex shape portion 5 is formed on the surface on the opposite side. In a configuration in which transparent portions 3 and concavoconvex shape portion 5 are formed on the same surface of transparent substrate 2, diffraction is effectively generated by concavoconvex shape portion 5 and a diffraction image is effectively formed. Accordingly, transparent portions 3 and concavoconvex shape portion 5 are preferably constituted by members that have sufficient difference in indices of refraction.

(Example of Application to a First Lighting Device)

Referring to FIG. 7, explanation next regards one example of first lighting device 60 on which micro-louver 1 of the present invention is mounted. FIG. 7 is a side view showing a schematic view of lighting device 60. FIG. 7 shows the major parts of lighting device 60, and details of, for example, the frame that supports each of the parts shown in the figure have been omitted from the drawing.

Lighting device 60 is of a configuration that includes reflection sheet 51 in the lowest portion of the figure and that, by reflection sheet 51, reflects light from light source 52 that is arranged obliquely upward on reflection sheet 51 so as to irradiate from the irradiation surface of the upper end of the figure. Light guide plate 53 and diffusion plate 54 are

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arranged in order over reflection sheet **51**. Light that has been reflected by reflection sheet **51** is scattered by diffusion plate **54**, whereby the amount of irradiated light is equalized over the entire surface of the irradiation surface. Prism sheet **55** is arranged over diffusion plate **54** and serves the role of adjusting to a certain degree the directionalities of light that has been scattered by diffusion plate **54**. Micro-louver **1** is mounted over this prism sheet **55**.

Micro-louver **1** is arranged with the side of transparent substrate **2** on which concavoconvex shape portion **5** is formed facing upward. Accordingly, light source **52**, reflection sheet **51**, light guide plate **53**, diffusion plate **54**, and prism sheet **55** make up a light source device that irradiates light over the entire surface of micro-louver **1** of the side opposite to the side of transparent substrate **2** on which concavoconvex shape portion **5** is formed.

By mounting micro-louver **1**, lighting device **60** is obtained having directivity in which the quantity of light in directions oblique to the light irradiation surface is limited. Moreover, a fixed image can be displayed in the angle region in which the amount of light is limited. This fixed image can be used for, for example, advertising.

As shown in FIG. **8**, micro-louver **1** may be adhered to prism sheet **55** via transparent adhesive layer **56**, whereby the reflection of light at the interface of micro-louver **1** and prism sheet **55** can be reduced and the loss of a quantity of light due to reflection can be decreased.

(Example of Application to a Second Lighting Device)

Referring to FIG. **9**, explanation next regards second lighting device **61** on which micro-louver **1** of the present invention is mounted. This lighting device **61** is a device in which first lighting device **60** is further provided with a transmission-scattering switching element (PDLC: Polymer Dispersed Liquid Crystal) **70** on the light emission side (upper side of the figure) of micro-louver **1**.

Transmission-scattering switching element **70** includes a polymer-dispersed liquid crystal layer **73**. Although detailed explanation is omitted, switching of the voltage applied to transparent electrodes **72**, each of which is fitted on the both surfaces of polymer-dispersed liquid crystal layer **73**, can bring about switching between a state in which incident light is scattered and a state in which incident light is transmitted. Transmission-scattering switching element **70** shown in the figure further includes transparent substrates **71** arranged on the outer side of each of transparent electrodes **72**.

In this lighting device **61**, the combination of micro-louver **1** and transmission-scattering switching element **70** enables switching between a state having directivity and a state lacking directivity. In other words, when transmission-scattering switching element **70** is switched to a state in which incident light is transmitted, illumination having directivity can be obtained by the operation of micro-louver **1**, as in the case of lighting device **50**. On the other hand, when transmission-scattering switching element **70** is switched to a state in which incident light is scattered, although light emitted from micro-louver **1** has directivity, this emitted light is scattered by transmission-scattering switching element **70**, thereby losing the directivity. The output from lighting device **61** is therefore illumination lacking directivity.

In this lighting device **61**, the incorporation of micro-louver **1** of the present invention enables the display of a fixed image in the angle region in which the emission of light is limited when transmission-scattering switching element **70** is switched to a state in which incident light is transmitted.

In addition, as shown in FIG. **10**, micro-louver **1** may also be adhered to transmission-scattering switching element **70** via transparent adhesive layer **74**, whereby the reflection of

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light at the interface of micro-louver **1** and transmission-scattering switching element **70** can be reduced, and the loss of an amount of light due to reflection can be decreased. (Example of Application to a First Display Device)

Referring to FIG. **11**, explanation next regards an example of first display device **80** on which micro-louver **1** of the present invention is mounted. LCD (Liquid Crystal Display) is used as the optical control element of this display device **80**. With the exception that micro-louver **1** is not arranged, a device of a configuration similar to the above-described first lighting device **60** is used as backlight device **57** of liquid crystal display panel **90**. In FIG. **11**, the reference numbers conferred to the constituent components of backlight device **57** are the same as ones in lighting device **60**, and detailed explanation is therefore omitted.

Liquid crystal display panel **90** includes liquid crystal layer **91** and color filter **92** provided on the display surface side (the upper side of the figure) of liquid crystal layer **91** for enabling the display of a color image. Liquid crystal layer **91** and color filter **92** are supported by transparent substrates **93** arranged on the obverse and reverse (on both the upper and lower sides in the figure), and polarizer/retarder plate **94** are arranged on the outer side of each of transparent substrates **93**.

Micro-louver **1** is arranged on the display surface side of liquid crystal display panel **90** such that transparent substrate **2** on which concavoconvex shape portion **5** is formed is directed toward the display side (upward in the figure). In this way, the amount of light, which is in a direction oblique to the display surface in the light that is emitted via liquid crystal display panel **90** from backlight device **57**, is limited. As a result, the ability to see a display image from a direction oblique to the display surface can be restricted, i.e., the visible angle range of display device **80** can be limited.

Furthermore, a fixed image formed by concavoconvex shape portion **5** of micro-louver **1** can be made visible from the angle region outside this visible angle range of display device **80**. For example, although the display image produced by liquid crystal display panel **90** becomes dim and hard to see in the angle region close to the boundaries between angle region A of micro-louver **1** in which light is emitted and angle region B in which the emission of light is limited (see FIG. **3**), the display image may still be somewhat visible in some cases. When the fixed image produced by concavoconvex shape portion **5** is displayed in such cases, this fixed image is displayed more brightly than the display image produced by liquid crystal display panel **90**, so that an observer more easily recognizes the fixed image. Thus, even when the display image produced by liquid crystal display panel **90** is dimly displayed, the ability to view the display image can be effectively restricted by the display of the fixed image.

In addition, liquid crystal display panel **90** is not limited to the transmission type, and although other components such as backlight device **57** may require alteration as appropriate, a transmissive type or a reflective type may also be used. In such cases, micro-louver **1** is arranged on the display surface side of liquid crystal display panel **90**, thereby obtaining the operation of limiting the visible angle range. Other optical control elements of light-emission type such as an organic EL (Organic Electroluminescence) display panel or PDP (Plasma Display Panel) may also be employed. In addition, a configuration may be adopted in which micro-louver **1** is adhered to the display surface of an optical control element. Alternatively, micro-louver **1** may be supplied separately from display device **80** and may be of a configuration such that the user adheres micro-louver **1** to the display surface of an existing display device. Still further, configurations are also possible in which a hard-coat layer as a measure for

protecting against scratches or a anti-reflection film is added to the observer-side surface of micro-louver **1** to restrict that the display is made hard to see by providing micro-louver **1**.

Display device **80** can be preferably used for, for example, a cellular phone or a portable computer such as a notebook PC. This use of micro-louver **1** in a portable electronic device can prevent the display screen from being viewed by others and can maintain the protection of privacy when the device is carried and used outside. Even in the case of a fixed electronic device, micro-louver **1** can be applied to, for example, a terminal for the input and output of information for which secrecy is required, thereby raising security.

(Example of Application to a Second Display Device)

Referring to FIG. **12**, explanation next regards second display device **81** on which micro-louver **1** of the present invention is mounted. This display device **81** is a device in which first display device **80** is further provided with touch panel **100** arranged on the surface of the display screen. The other constituent components of display device **81** are similar to those of first display device **80** and the same reference numbers are therefore applied, and detailed explanation is omitted.

Touch panel **100** is a device that detects the position on a screen touched by a person's finger or stylus dedicated for this purpose, and may be of any publicly known configuration. In the example shown in FIG. **12**, touch panel **100** includes functional layer **101**, transparent electrodes **102** and transparent substrates **103** on and over each of the obverse and reverse of functional layer **101**, respectively.

In display device **81**, micro-louver **1** is arranged between liquid crystal display panel **90** and touch panel **100**. Micro-louver **1** is arranged such that transparent substrate **2** on which concavoconvex shape portion **5** is formed is directed toward the side of touch panel **100**, i.e., the display side. This micro-louver **1** obtains the operation of limiting the visible angle range. In this case, a fixed image formed by concavoconvex shape portion **5** of micro-louver **1** can be made visible from angle regions outside the visible angle range of display device **81**.

As shown in FIG. **13**, micro-louver **1** and touch panel **100** may be adhered together via transparent adhesive layer **104**. As a result, the loss of light amount due to surface reflection can be reduced. Further, as shown in FIG. **14**, micro-louver **1** and liquid crystal display panel **90** can be adhered together via transparent adhesive layer **97**. In addition to the operation of decreasing loss of an amount of light, this adhesion obtains the operation of suppressing the introduction of extraneous matter between touch panel **100** and liquid crystal display panel **90**.

Further, as shown in FIG. **15**, micro-louver **1** may be arranged on the surface of touch panel **100**, or may be adhered via transparent adhesive layer **105** as shown in FIG. **16**.

Display device **81** can be preferably used in, for example, an ATM (Automated Teller Machine) terminal. The use of display device **81** in an ATM terminal can prevent the display screen from being viewed by persons other than the user of the ATM terminal, who are located directly in front of the display screen, and can thus increase security. In addition, the fixed image formed by concavoconvex shape portion **5** can be made visible to persons located around an ATM terminal, whereby this fixed image can be used for, for example, advertising. Moreover, as previously described, when using an ATM terminal, the display of the fixed image can render the original display screen hard to be recognized by persons other than the user, thereby enabling to achieve an increase in security.

This application is based upon and claims the benefit of priority from Japanese Patent Application No. 2006-279994, filed on Oct. 13, 2006, the disclosure of which is expressly incorporated herein in its entirety by reference.

While exemplary embodiments of the present invention have been described using specific terms, such description is for illustrative purposes. It is to be understood that the invention is not limited to exemplary embodiments or constructions. To the contrary, the invention is intended to cover various modifications and equivalent arrangements. In addition, while the various elements of exemplary embodiments are shown in various combinations and configurations, which are exemplary, other combinations and configurations, including more, less or only a single element, are also within the spirit and scope of the invention as defined in the following claims.

What is claimed is:

1. A display device comprising:

(a) an optical element comprising:

a transparent substrate,

a concavoconvex shape portion formed on at least one surface of the transparent substrate and in a prescribed pattern for diffracting incident light to form an image, wherein said concavoconvex shape portion is a transmissive-type diffraction grating that generates a diffraction image, and

a light controlling layer including at least one transparent portion and at least one light-absorption portion arranged alternately on said at least one surface of the transparent substrate, each of said at least one transparent portion and said at least one light-absorption portion extending in a direction that intersects said at least one surface; and

(b) an optical control element for forming a display image, wherein the optical element is arranged on a display surface side of the optical control element such that a surface of the optical element, which is on a side opposite to a side of the transparent substrate on which the concavoconvex shape portion is formed, faces the optical control element,

wherein said at least one transparent portion and said at least one light-absorption portion are constituted to display the display image in a first angle region located in a front direction with regard to a display surface of the optical element, wherein the display image has a higher amount of light than an image formed by the concavoconvex shape portion, and

wherein the concavoconvex shape portion is constituted to display the image in a second angle region located in an oblique direction with regard to the display surface of the optical element, wherein the image has a higher amount of light than the display image.

2. The display device according to claim **1**, wherein the concavoconvex shape portion and said at least one transparent portion are formed on a same surface of the transparent substrate and are formed by members having different indices of refraction.

3. The display device according to claim **1**, wherein the concavoconvex shape portion is formed by a member that differs from the transparent substrate and that is bonded onto the transparent substrate.

4. The display device according to claim **1**, further comprising a touch panel, wherein the touch panel is arranged on the display surface side of the optical control element.

5. An electronic device comprising:

the display device according to claim **1**

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wherein the at least one light-absorption portion limits the emission of light in a direction that is oblique with respect to the transparent substrate, and wherein the image is a fixed diffraction image that corresponds to the prescribed pattern.

6. A cellular phone comprising:

the display device according to claim 1

wherein the at least one light-absorption portion limits the emission of light in a direction that is oblique with respect to the transparent substrate, and

wherein the image is a fixed diffraction image that corresponds to the prescribed pattern.

7. A portable computer comprising:

a display device according to claim 1;

wherein the at least one light-absorption portion limits the emission of light in a direction that is oblique with respect to the transparent substrate, and

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wherein the image is a fixed diffraction image that corresponds to the prescribed pattern.

8. An automated teller machine comprising:

a display device according to claim 1;

wherein the at least one light-absorption portion limits the emission of light in a direction that is oblique with respect to the transparent substrate, and

wherein the image is a fixed diffraction image that corresponds to the prescribed pattern.

9. The automated teller machine according to claim 8, further comprising a touch panel, wherein the touch panel is arranged on the display surface side of the optical control element.

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